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(54) Method and apparatus for extending security model to native code

(57) A wireless data platform (10) comprises a plurality of processors (12, 16). Channels of communication are set up between processors such that they may communicate information as tasks are performed. A dynamic cross compiler (80) executed on one processor compiles code into native processing code for another processor. A dynamic cross linker (82) links the compiled code for other processor. Native code may also be downloaded to the platform through use of a JAVA Bean (90) (or other language type) which encapsulates the native code. The JAVA Bean can be encrypted and digitally signed for security purposes.

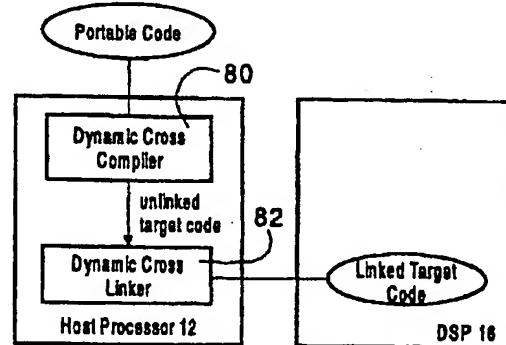


Fig. 3

EP 0 930 567 A3



EUROPEAN SEARCH REPORT

Application Number
EP 98 31 0592

DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
|--|---|-----------------------------|--|
| X | EP 0 706 275 A (IBM) 10 April 1996 (1996-04-10) * page 2, line 15 - line 17 * * page 5, line 48 - page 10, line 36 * | 1,3-15, 17-19 | G06F9/445 G06F1/00 G06F12/14 |
| X | EP 0 778 522 A (SUN MICROSYSTEMS INC) 11 June 1997 (1997-06-11) | 7,8,11, 12,15, 17,18 | |
| A | * page 5, line 32 - page 9, line 24 * | 1,3-6,9, 10,13, 14,19 | |
| TECHNICAL FIELDS SEARCHED (Int.Cl.6) | | | |
| G06F | | | |
| The present search report has been drawn up for all claims | | | |
| Place of search | Date of completion of the search | Examiner | |
| THE HAGUE | 11 August 2000 | Bijn, K | |
| CATEGORY OF CITED DOCUMENTS | | | |
| X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document | | | |
| T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document | | | |

EP 0 930 567 A3
ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 98 31 0592

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-08-2000

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| | | JP | 10069382 A | 10-03-1998 |

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/01215

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04K 1/00

US CL :380/25, 4, 30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/25, 4, 30, 23, 24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| A, E | US 5,724,425 A (CHANG, et al.) 03 March 1998, (03/03/98) | 1-22 |
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Further documents are listed in the continuation of Box C.

See patent family annex.

| | | |
|---|-----|--|
| * Special categories of cited documents: | | |
| *A* document defining the general state of the art which is not considered to be of particular relevance | *T* | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
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| *O* document referring to an oral disclosure, use, exhibition or other means | *&* | document member of the same patent family |

Date of the actual completion of the international search

05 JUNE 1998

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10 JUL 1998

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

5 [0001] This application is related to U.S. Ser. No. 08/995,606, entitled "Mobile Information Services Platform" (Atty Docket No. 26421) to McMahon et al, U.S. Ser. No. 08/995,600 entitled "Mobile Communication System with Cross Compiler and Cross Linker" (Atty Docket No. 26453) to Woolsey et al, and U.S. Ser. No. 08/995,597, entitled "Method and Apparatus for Providing Downloadable Functionality to an Embedded Coprocessor" (Atty Docket No. 26440) to Brewer, all filed on even date herewith and incorporated by reference herein. Copies of these documents have been
10 placed on the public part of the file and are available to public inspection in accordance with Art. 128(4) EPC.

BACKGROUND OF THE INVENTION

1. TECHNICAL FIELD

15 [0002] This invention relates in general to mobile electronic devices and, more particularly, but not exclusively, to a hardware and software platform for mobile electronic devices.

2. DESCRIPTION OF THE RELATED ART

20 [0003] Handheld portable devices are gaining popularity as the power and, hence, functionality of the devices increases. Personal Digital Assistants (PDAs) are currently in widespread use and Smartphones, which combine the some of the capabilities of a cellular phone and a PDA, are expected to have a significant impact on communications in the near future.

25 [0004] Some devices currently incorporate one or more DSPs (digital signal processor) or other coprocessors for providing certain discrete features, such as voice recognition, and a general purpose processor for the other data processing functions. The code for the DSP and the code for the general purpose processor is generally stored in ROMs or other nonvolatile memories, which are not easily modified. Thus, as improvements and new features become available, it is often not possible to upgrade the capabilities of the device. In particular, it is not possible to maximize the use of the
30 DSPs or other coprocessor which may be present in the device.

[0005] Therefore, a need exists for a data processing architecture which can be upgraded and optimizes use of multiple processors and coprocessors.

BRIEF SUMMARY OF THE INVENTION

35 [0006] In a first embodiment of the present invention, a file of native code within an software program including source code is stored in an external device, which encrypts both the source code and the native code in the software program. The encrypted software program is downloaded to the electronic device, where the software program is decrypted and the native code is retrieved. The native code is installed on a target processor where it is executed.

40 [0007] In a second embodiment of the present invention, a file of native code within an software program including source code is stored in an external device, which applies a digital signature to the software program. The software program is downloaded to the electronic device, where the signature is verified. Responsive to the verification, the native code is retrieved and installed on a target processor where it is executed.

[0008] Embodiments of the present invention provide significant advantages. Where the native code is encrypted during transmission along with the code of the software program, unauthorized modification of the code is prevented. Where a digital signature is applied to the software program, the authenticity of the code can be verified. Because the native code is secure and comes from a trusted source, the attributes of the native code can also be trusted as accurate. Where the software program is a JAVA Bean, the built in security processes of JAVA can be used to encrypt and sign the Bean and, hence, the native code.

50 **BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS**

[0009] Embodiments of the present invention, will now be described, by way of example only, and taken in conjunction with the accompanying drawings, in which:

55 Figure 1 illustrates a block diagram of a platform architecture particularly suited for general wireless data processing;

EP 0 930 567 A2

Figure 2 illustrates a functional block diagram of the platform of Figure 1;

Figure 3 illustrates a functional block diagram of dynamic cross compiling and dynamic cross linking functions;

5 Figure 4 illustrate an embodiment of native code for execution on a processor being encapsulated in a JAVA Bean wrapper for downloading to a device;

10 Figure 5 illustrates the operation of transferring the encapsulated native code to a processor on a device from a JAVA Bean located on a remote server; and

Figure 6 illustrates a flow diagram describing security features associated with the operation of Figure 5.

DETAILED DESCRIPTION OF THE INVENTION

15 [0010] In the following description like numerals are used for like elements of the various drawings.

[0011] Figure 1 illustrates a preferred embodiment of a general wireless data platform architecture, which could be used for example, in the implementation of a Smartphone or PDA. The wireless data platform 10 includes a general purpose (Host) processor 12 coupled to bus structure 14, including data bus 14a, address bus 14b and control bus 14c. One or more DSPs (or other coprocessors) 16, including the core processor 16a and the peripheral interface 16b, are coupled to bus 14 and to memory and traffic controller 18, which includes a DSP cache memory 18a, a CPU cache 18b, and a MMU (memory management unit) 18c. A hardware accelerator circuit 20 (for accelerating a portable language such as JAVA) and a video and LCD controller 22 are also coupled to the memory and traffic controller 18. The output of the video and LCD controller is coupled to a LCD or video display 24.

[0012] Memory & traffic controller 18 is coupled to bus 14 and to the main memory 26, shown as an SDRAM (synchronous dynamic random access memory). Bus 14 is also connected to I/O controller 28, interface 30, and RAM/ROM 32. A plurality of devices could be coupled to the wireless data platform 10, such as smartcard 34, keyboard 36, mouse 38, or one or more serial ports 40, such as a USB (universal serial bus) port or an RS232 serial port. Interface 30 can couple to a flash memory card 42 and/or a DRAM card 44. The peripheral interface 16b can couple the DSP 16 to a DAC (digital to analog converter) 46, a network interface 48 or to other devices.

[0013] The wireless data platform 10 of Figure 1 utilizes both a general purpose processor 12 and a DSP 16. Unlike current devices in which the DSP 16 is dedicated to specific fixed functions, the DSP 16 of Figure 1 can be used for any number of functions. This allows the user to derive the full benefit of the DSP 16.

[0014] One main area in which the DSP 16 can be used is in connection with the man-machine interface (MMI). Importantly, functions like speech recognition, image and video compression and decompression, data encryption, text-to-speech conversion, and so on, can be performed much more efficiently using the DSP 16. The present architecture allows new functions and enhancements to be easily added to wireless data platform 10.

[0015] It should be noted that the wireless data platform 10 is a general block diagram and many modifications could be made. For example, Figure 1 illustrates separate DSP and processor caches 18a and 18b. As would be known to one skilled in the art, a unified cache could also be used. Further, the hardware acceleration circuit 20 is an optional item. Such devices speed the execution of languages such as JAVA; however, the circuit is not necessary for operation of the device. Further, although the illustrated embodiment shows a single DSP, multiple DSPs (or other coprocessors) could be coupled to the buses.

[0016] Figure 2 illustrates a functional software architecture for the wireless data platform 10. This block diagram presumes the use of JAVA; it should be noted that languages other than JAVA could be used as well. Functionally, the software is divided into two groups, Host processor software and DSP software. The Host software includes one or more applets 40. The DSP API class 42 is a JAVA API package for JAVA applications or applets to access the functionality of the DSP API 50 and Host-DSP Interface Layer 52. A JAVA virtual machine (VM) 44 interprets the applets. The JAVA native interface 46 is the method which the JAVA VM executes host processor or platform specific code. Native tasks 48 are non-JAVA programs which can be executed by the Host processor 12 without using the JAVA native interface.

50 The DSP API 50, described in greater detail hereinbelow, is an API (application program interface) used the Host 12 to call to make use of the capabilities of the DSP 16. The Host-DSP Interface Layer 52 provides an API for the Host 12 and DSP 16 to communicate with each other, with other tasks, or other hardware using channels via the Host-DSP Communication Protocol. The DSP device driver 54 is the Host based device driver for the Host RTOS 56 (real time operating system) to communicate with the DSP 16. The Host RTOS 56 is an operating system, such as NUCLEUS

55 PLUS by Accelerated Technology Incorporated. Alternatively a non-real time operating system, such as WINDOWS CE by Microsoft Corporation, could be used. The DSP Library 58 contains programs stored for execution on the DSP 16.

[0017] On the DSP side, one or more tasks 60 can be stored in memory for execution by the DSP16. As described below, the tasks can be moved in and out of the memory as desired, such that the functionality of the DSP is dynamic,

rather than static. The Host-DSP Interface layer 62 on the DSP side performs the same function as the Host-DSP Interface layer 52 on the Host side, namely it allows the Host 12 and DSP 16 to communicate. The DSP RTOS 64 is the operating system for the DSP processor. The Host Device driver 66 is a DSP based device driver for the DSP RTOS 64 to communicate with the Host 12. The Host-DSP Interface 70 couples the DSP 16 and Host 12.

5 [0018] In operation, the software architecture shown in Figure 2 uses the DSP 16 as a variable function device, rather than a fixed function device as in the prior art. Accordingly, the DSP functions can be downloaded to the mobile device incorporating the architecture of Figure 2 to allow the DSP 16 to perform various signal processing functions for the Host 12.

10 **DSP-API**

[0019] The DSP-API provides a device independent interface from the Host 12 to the DSP 16. The functions provide the Host 12 with the ability to load and schedule tasks on the DSP 16 and to control and communicate with those tasks. The API functions include calls to: determine the DSP's available resources, create and control Host 12 and DSP tasks, 15 create and control data channels between Host 12 and DSP tasks, and communicate with tasks. These functions are described below. Each function returns a BOOL result, which will be SUCCESS for a successful operation, or FAILURE. If the result is FAILURE, the *errcode* should be checked to determine which error occurred.

DSP_Get_MIPS

20 *BOOL DSP_Get_MIPS(T_DeviceID DevID, U32 *mips, U16 *errcode);*

[0020] This function returns the current MIPS available on the DSP. This consists of the MIPS capability of the DSP 16 minus a base MIPS value (the MIPS value with no additional dynamic tasks, i.e. the kernel plus API code plus drivers), minus the sum of the MIPS ratings for all loaded dynamic tasks. The *errcode* parameter will contain the following 25 possible results:

DSP_SUCCESS
DSP_DEVID_NOT_FOUND
30 DSP_DEVID_NOT_RESPONDING

DSP_Get_Memory_Available

35 *BOOL DSP_Get_Memory_Available(T_DeviceID DevID, T_Size *progmem, T_Size *datamem, U16 *errcode);*

[0021] This function will query the DSP 16 specified by *DevID* for the amounts of available memory for both program memory and data memory. The resultant values are returned in the *progmem* and *datamem* parameters. The sizes are specified in T_DSP_Words. The *errcode* parameter will contain the following possible results:

40 DSP_SUCCESS
DSP_DEVID_NOT_FOUND
DSP_DEVID_NOT_RESPONDING

DSP_Alloc_Mem

45 *BOOL DSP_Alloc_Mem(T_DeviceID DevID, U16 mempage, T_Size size, T_DSP_Word **memptr, U16 *errcode);*

[0022] This function will allocate a block of memory on a DSP 16. The *DevID* specifies which device on which to allocate the memory. The *mempage* is 0 for program space, and 1 for data space. The *size* parameter specifies the memory block size in T_DSP_Words. The returned *memptr* will be a pointer to the memory block on the DSP 16, or NULL on failure. The *errcode* parameter will contain the following possible results:

55 DSP_SUCCESS
DSP_DEVID_NOT_FOUND
DSP_DEVID_NOT_RESPONDING
DSP_INVALID_MEMPAGE
DSP_NOT_ENOUGH_MEMORY

DSP_Free_Mem

```
BOOL DSP_Free_Mem(T_DeviceID DevID, U16 mempage, T_DSP_Word *memptr, U16 *errcode);
```

5 [0023] This function will free a block of memory on a DSP that was allocated with the DSP_Alloc_Mem function. The *DevID* specifies on which device the memory resides. The *mempage* is 0 for program space, and 1 for data space. The *memptr* parameter is the pointer to the memory block. The *errcode* parameter will contain the following possible results:

```
DSP_SUCCESS
10 DSP_DEVID_NOT_FOUND
    DSP_DEVID_NOT_RESPONDING
    DSP_INVALID_MEMPAGE
    DSP_MEMBLOCK_NOT_FOUND
```

DSP_Get_Code_Info

```
BOOL DSP_Get_Code_Info(char *Name, T_CodeHdr *codehdr, U16 *errcode);
```

20 [0024] This function will access the DSP Library table and return the code header for the DSP function code specified by the *Name* parameter. On return, the location pointed to by the *codehdr* parameter will contain the code header information. The *errcode* parameter will contain the following possible results:

```
DSP_SUCCESS
25 DSP_NAMED_FUNC_NOT_FOUND
```

DSP_Link_Code

```
BOOL DSP_Link_Code(T_DeviceID DevID, T_CodeHdr *codehdr, T_TaskCreate *tcs, U16 *errcode);
```

30 [0025] This function will link DSP function code so that it will run at a specified address on the DSP specified by *DevID*. The *codehdr* parameter points to the code header for the function. The dynamic cross linker will link the code based on information in the code header, and in the code (COFF file). The dynamic cross linker will allocate the memory as needed, and link and load the code to the DSP 16. The *tcs* parameter is a pointer to the task creation structure needed in the DSP_Create_Task function. DSP_Link_Code will fill in the code entry points, priority, and quantum fields of the structure in preparation for creating a task. The *errcode* parameter will contain the following possible results:

```
DSP_SUCCESS
35 DSP_DEVID_NOT_FOUND
    DSP_DEVID_NOT_RESPONDING
    DSP_NOT_ENOUGH_PROG_MEMORY
    DSP_NOT_ENOUGH_DATA_MEMORY
    DSP_COULD_NOT_LOAD_CODE
```

DSP_Put_BLOB

45 [0026] This function will copy a specified Binary Large Object (BLOB) to the DSP 16. The *DevID* specifies on which DSP 16 to copy the object. The *srcaddr* parameter is a pointer to the object in Host memory. The *destaddr* is a pointer to the location to which to copy the object on the DSP 16. The *mempage* is 0 for program space, and 1 for data space. The *size* parameter specifies the size of the object in T_DSP_Words. The *errcode* parameter will contain the following possible results:

```
55 DSP_SUCCESS
    DSP_DEVID_NOT_FOUND
    DSP_DEVID_NOT_RESPONDING
    DSP_INVALID_MEMPAGE
```

DSP_Create_Task

*BOOL DSP_Create_Task(T_DeviceID DevID, T_TaskCreate *tcs, T_TaskID *TaskID, U16 *errcode);*

5 [0027] DSP_Create_Task requests the DSP 16 to create a task given the task parameters and the code locations in the DSP's program space. The Task Creation Structure is show in Table 1:

Table 1

| Task Creation Structure. | | |
|--------------------------|------------|--|
| Data Type | Field Name | Description |
| T_DSP_Name | Name | User defined name for the task. |
| U32 | MIPS | MIPS used by the task. |
| T_ChainID | ChanIn | The channel ID used for task input. |
| T_ChainID | ChanOut | The channel ID used for task output. |
| T_StrmID | StrmIn | The stream ID used for task input. |
| T_StrmID | StrmOut | The stream ID used for task output. |
| U16 | Priority | The task's priority. |
| U32 | Quantum | The task's timeslice in system ticks. |
| T_Size | StackReq | The amount of stack required. |
| T_DSP_Ptr | MsgHandler | Pointer to code to handle messages to the task. |
| T_HOST_Ptr | CallBack | Pointer to Host code to handle messages from the task. |
| T_DSP_Ptr | Create | Pointer to code to execute when task is created. |
| T_DSP_Ptr | Start | Pointer to code to execute when task is started. |
| T_DSP_Ptr | Suspend | Pointer to code to execute when task is suspended. |
| T_DSP_Ptr | Resume | Pointer to code to execute when task is resumed. |
| T_DSP_Ptr | Stop | Pointer to code to execute when task is stopped. |

40 [0028] Once the task is created, the Create entry point will be called, giving the task the opportunity to do any necessary preliminary initialization. The Create, Suspend, Resume, and Stop entry points can be NULL. The resultant TaskID contains both the device ID (DevID), and the DSP's task ID. If the TaskID is NULL, the create failed. The errcode parameter will contain the following possible results:

DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 45 DSP_DEVID_NOT_RESPONDING
 DSP_INVALID_PRIORITY
 DSP_CHANNEL_NOT_FOUND
 DSP_ALLOCATION_ERROR

DSP_Start_Task

*BOOL DSP_Start_Task(T_TaskID TaskID, U16 *errcode);*

55 [0029] This function will start a DSP task specified by TaskID. Execution will begin at the task's Start entry point. The errcode parameter will contain the following possible results:

DSP_SUCCESS
 DSP_DEVID_NOT_FOUND

DSP_DEVID_NOT_RESPONDING
DSP_TASK_NOT_FOUND

DSP_Suspend_Task

5 *BOOL DSP_Suspend_Task(T_TaskID TaskID, U16 *errcode);*

[0030] This function will suspend a DSP task specified by *TaskID*. Prior to being suspended, the task's Suspend entry point will be called to give the task a chance to perform any necessary housekeeping. The *errcode* parameter will contain the following possible results:

10 DSP_SUCCESS
DSP_DEVID_NOT_FOUND
DSP_DEVID_NOT_RESPONDING
15 DSP_TASK_NOT_FOUND

DSP_Resume_Task

20 *BOOL DSP_Resume_Task(T_TaskID TaskID, U16 *errcode);*

[0031] This function will resume a DSP task that was suspended by *DSP_Suspend_Task*. Prior to being resumed, the task's Resume entry point will be called to give the task a chance to perform any necessary housekeeping. The *errcode* parameter will contain the following possible results:

25 DSP_SUCCESS
DSP_DEVID_NOT_FOUND
DSP_DEVID_NOT_RESPONDING
DSP_TASK_NOT_FOUND
30 DSP_TASK_NOT_SUSPENDED

DSP_Delete_Task

*BOOL DSP_Delete_Task(T_TaskID TaskID, U16 *errcode);*

35 [0032] This function will delete a DSP task specified by *TaskID*. Prior to the deletion, the task's Stop entry point will be called to give the task a chance to perform any necessary cleanup. This should include freeing any memory that was allocated by the task, and returning any resources the task acquired. The *errcode* parameter will contain the following possible results:

40 DSP_SUCCESS
DSP_DEVID_NOT_FOUND
DSP_DEVID_NOT_RESPONDING
DSP_TASK_NOT_FOUND

DSP_Change_Task_Priority

*BOOL DSP_Change_Task_Priority(T_TaskID TaskID, U16 newpriority, U16 *oldpriority, U16 *errcode);*

50 [0033] This function will change the priority of a DSP task specified by *TaskID*. The priority will be changed to *newpriority*. The possible values of *newpriority* are RTOS dependent. Upon return, the *oldpriority* parameter will be set to the previous priority of the task. The *errcode* parameter will contain the following possible results:

55 DSP_SUCCESS
DSP_DEVID_NOT_FOUND
DSP_DEVID_NOT_RESPONDING
DSP_TASK_NOT_FOUND
DSP_INVALID_PRIORITY

DSP_Get_Task_Status

*BOOL DSP_Get_Task_Status(T_TaskID TaskID, U16 *status, U16 *priority, T_ChainID *Input, T_ChainID *Output, U16 *errcode);*

5 [0034] This function returns the status for a DSP task specified by *TaskID*. The *status* will be one of the following values:

10 DSP_TASK_RUNNING
 DSP_TASK_SUSPENDED
 DSP_TASK_WAITFOR_SEM
 DSP_TASK_WAITFOR_QUEUE
 DSP_TASK_WAITFOR_MSG

15 [0035] The *priority* parameter will contain the task's priority, and the *Input* and *Output* parameters will contain the task's input and output channel IDs, respectively. The *errcode* parameter will contain the following possible results:

20 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_TASK_NOT_FOUND

DSP_Get_ID_From_Name

25 *BOOL DSP_Get_ID_From_Name(T_DeviceID DevID, T_DSP_Name Name, T_DSP_ID *ID, U16 *errcode);*

30 [0036] This function returns the *ID* for a named object on the DSP 16. The named object may be a channel, a task, a memory block, or any other supported named DSP object. The *errcode* parameter will contain the following possible results:

35 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_NAME_NOT_FOUND

DSP_Dbg_Read_Mem

40 *BOOL DSP_Dbg_Read_Mem(DEVICE_ID DevID, U8 mempage, DSP_PTR addr, U32 count, DSP_WORD *buf, U16 *errcode);*

45 [0037] This function requests a block of memory. The *mempage* specifies program memory (0) or data memory (1). The *addr* parameter specifies the memory starting address, and the *count* indicates how many *T_DSP_Words* to read. The *buf* parameter is a pointer to a caller provided buffer to which the memory should be copied. The *errcode* parameter will contain the following possible results:

50 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_INVALID_MEMPAGE

DSP_Dbg_Write_Mem

55 *BOOL DSP_Dbg_Write_Mem(T_DeviceID DevID, U16 mempage, T_DSP_Ptr addr, T_Count count, T_DSP_Word *buf, U16 *errcode);*

59 [0038] This function writes a block of memory. The *mempage* specifies program memory (0) or data memory (1). The *addr* parameter specifies the memory starting address, and the *count* indicates how many *T_DSP_Words* to write. The *buf* parameter is a pointer to the buffer containing the memory to write. The *errcode* parameter will contain the following

possible results:

5 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_INVALID_MEMPAGE

DSP_Dbg_Read_Reg

10 *BOOL DSP_Dbg_Read_Reg(T_DeviceID DevID, U16 RegID, T_DSP_Word *regvalue, U16 *errcode);*

[0039] This function reads a DSP register and returns the value in *regvalue*. The *RegID* parameter specifies which register to return. If the *RegID* is -1, then all of the register values are returned. The *regvalue* parameter, which is a pointer to a caller provided buffer, should point to sufficient storage to hold all of the values. The register IDs are DSP specific and will depend on a particular implementation. The *errcode* parameter will contain the following possible results:

20 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_INVALID_REGISTER

DSP_Dbg_Write_Reg

25 *BOOL DSP_Dbg_Write_Reg(T_DeviceID DevID, U16 RegID, T_DSP_Word regvalue, U16 *errcode);*

[0040] This function writes a DSP register. The *RegID* parameter specifies which register to modify. *regvalue* contains the new value to write. The register IDs are DSP specific and will depend on a particular implementation. The *errcode* parameter will contain the following possible results:

30 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_INVALID_REGISTER

DSP_Dbg_Set_Break

*BOOL DSP_Dbg_Set_Break(T_DeviceID DevID, DSP_Ptr addr, U16 *errcode);*

40 [0041] This function sets a break point at the given code address (*addr*). The *errcode* parameter will contain the following possible results:

45 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING

DSP_Dbg_Clr_Break

*BOOL DSP_Dbg_Clr_Break(T_DeviceID DevID, T_DSP_Ptr addr, U16 *errcode);*

50 [0042] This function clears a break point that was previously set by *DSP_Dbg_Set_Break* at the given code address (*addr*). The *errcode* parameter will contain the following possible results:

55 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_BP_DID_NOT_EXIST

DSP DEVICE DRIVER

5 [0043] The DSP Device Driver 54 handles communications from the Host 12 to the DSP 16. The driver functions will take the communication requests as specified in the Host-DSP Communications Protocol and handle the transmission of the information via the available hardware interface. The device driver is RTOS dependent and communications hardware dependent.

DSP LIBRARY

10 [0044] The DSP Library 58 contains the blocks of code that can be downloaded to the DSP 16 for execution. Each block of code will be previously unlinked, or relocatably linked as a library, so that the dynamic cross linker can resolve all address references. Each code block will also include information about the block's requirements for DSP MIPS (millions of instructions per second), priority, time slice quantum, and memory. The format for the code block header is shown in Table 2. The program memory and data memory sizes are approximations to give the Host 12 a quick check 15 on whether the DSP can support the task's memory requirements. If there appears to be sufficient space, the dynamic cross linker can then attempt to link and load the code. It should be noted that the dynamic cross linker could still fail, due to page alignment and contiguity requirements. In the preferred embodiment, the code is in a version 2 COFF file format.

20

Table 2

| Code Block Header. | | |
|--------------------|--------------|---|
| Data Type | Field Name | Description |
| 25 U16 | Processor | The target processor type. |
| T_DSP_Name | Name | Task's name. |
| U32 | MIPS | Worst case MIPS required by the task. |
| 30 T_Size | ProgSize | Total program memory size needed. |
| T_Size | DataSize | Total data memory size needed. |
| T_Size | InFrameSize | Size of a frame in the task's input channel. |
| T_Size | OutFrameSize | Size of a frame in the task's output channel. |
| 35 T_Size | InStrmSize | Size of the task's input stream FIFO. |
| T_Size | OutStrmSize | Size of the task's output stream FIFO. |
| U16 | Priority | Task's priority. |
| 40 U32 | Quantum | Task's time slice quantum (number of system ticks). |
| T_Size | StackReq | Stack required. |
| T_Size | CoffSize | Total size of the COFF file. |
| T_DSP_Ptr | MsgHandler | Offset to a message handler entry point for the task. |
| 45 T_DSP_Ptr | Create | Offset to a create entry point that is called when the task is created. |
| T_DSP_Ptr | Start | Offset to the start of the task's code. |
| T_DSP_Ptr | Suspend | Offset to a suspend entry point that is called prior to the task being suspended. |
| 50 T_DSP_Ptr | Resume | Offset to a resume entry point that is called prior to the task being resumed. |
| T_DSP_Ptr | Stop | Offset to a stop entry point that is called prior to the task being deleted. |
| T_Host_Ptr | CoffPtr | Pointer to the location of the COFF data in the DSP Library. |

55 **CONVERSION OF PORTABLE CODE INTO LINKED TARGET CODE**

[0045] A procedure for converting portable (processor independent) code, such as JAVA code, into linked target code is shown in Figure 3. The procedure uses two functions, a dynamic cross compiler 80 and a dynamic cross linker 82.

Each function is implemented on the host processor 12. The dynamic cross linker is part of the DSP-API in the preferred embodiment. The cross compiler may also be part of the DSP-API.

5 [0046] The dynamic cross compiler 80 converts portable code into unlinked, executable target processor code. The dynamic cross linker 82 converts the unlinked, executable target processor code into linked, executable target processor code. To do so, it must resolve addresses within a block of code, prior to loading on the DSP 16. The dynamic cross linker 82 links the code segments and data segments of the function, allocates the memory on the DSP 16, and loads the code and constant data to the DSP 16. The functions are referred to as "cross" compiling and "cross" linking, because the functions (compiling and linking) occur on a different processor (i.e., the host processor 12) from the target processor which executes the code (i.e., the DSP 16).

10 [0047] The dynamic cross compiler 80 accepts previously unlinked code loaded on demand by a user or a user agent (such as a browser). The code is processed to either (1) identify "tagged" sections of the code or (2) analyze untagged code segments for suitability of execution on the DSP 16. A tagged section of source code could delineate source targetable to a DSP by predetermined markers such as "(start DSP code)" and "(end DSP code)" embedded in the source code. If a tagged section is identified either directly or through analysis, a decision is made to either cross compile or 15 not based on the current processing state of the DSP 16. If a decision is made to compile, the section of code processed by compiling software that outputs unlinked, executable target processor code, using well known compiling methods. A decision not to compile could be made if for example, the DSP has insufficient available processing capacity (generally stated as available MIPS - million of instructions per second) or insufficient available memory, due to other tasks being executed by the DSP 16. The compiled code can be passed to the dynamic cross linker 82 for immediate 20 use in the DSP 16, or could be saved in the DSP library 58.

25 [0048] The dynamic cross linker 82 accepts previously unlinked code, which is either (1) statically stored in connection with the host processor 12 or (2) dynamically downloaded to the host processor 12 over a network connection (including global networks such as the Internet) or (3) dynamically generated by the dynamic cross compiler 80. The dynamic cross linker 82 links the input code for a memory starting address of the DSP 16 determined at runtime. The memory starting address can be determined from a memory map or memory table stored on and managed by either the host processor 12 or DSP 16. The dynamic cross linker 82 converts referenced memory locations in the code to actual memory locations in the DSP. These memory locations could include, for example, branch addresses in the code or references to locations of data in the code.

30 [0049] In the preferred embodiment, the portable code is in a COFF (common object file format) which contains all information about the code, including whether it is linked or unlinked. If it is unlinked, symbol tables define the address which must be changed for linking the code.

35 [0050] The conversion process described above has several significant advantages over the prior art. First, the dynamic cross compiler 80 allows run-time decisions to be made about where to execute the downloaded portable code. For example, in a system with multiple target processors (such as two DSPs 16), the dynamic cross compiler 80 could compile the portable code to any one of the target processors based on available resources or capabilities. The dynamic cross linker 82 provides for linking code to run on a target processor which does not support relocatable code. Since the code is linked at run-time, memory locations in the DSP 16 (or other target processor) do not need to be reserved, allowing optimum efficiency of use of all computing resources in the device. Because the compiling is accomplished with knowledge of the architecture of the platform 10, the compiling can take advantage of processor and platform specific features, such as intelligent cache architectures in one or both processors.

40 [0051] Thus, the DSP 16 can have various functions which are changed dynamically to fully use its processing capabilities. For example, the user may wish to load a user interface including voice recognition. At that time, the host processor could download software and dynamically cross compile and cross link the voice recognition software for execution in the DSP 16. Alternatively, previously compiled software in the DSP library 58 could be dynamically cross linked, based on the current status of the DSP 16, for execution.

HOST DEVICE DRIVER

50 [0052] The Host Device Driver handles communications from the DSP 16 to the Host 12. The driver functions takes the communication requests as specified in the Host-DSP Communications Protocol and handles transmission of the information via the available hardware interface. The device driver is RTOS dependent and communications hardware dependent.

HOST-DSP COMMUNICATIONS PROTOCOL (HOST-DSP INTERFACE LAYER)

55 [0053] The Host-DSP Communications Protocol governs the communications of commands and data between the Host 12 and the DSP 16. The communications consist of several paths: messages, data channels, and streams. Messages are used to send initialization parameters and commands to the tasks. Data channels carry large amounts of

data between tasks and between the DSP 16 and Host 12, in the form of data frames. Streams are used to pass streamed data between tasks and between the DSP 16 and Host 12.

Messages

5 [0054] Each task has an entry point to a message handler, which handles messages. The messages are user defined and will include initialization parameters for the task's function, and commands for controlling the task. The tasks send messages to the Host 12 via the callback specified when the task is created. The prototype for the task's message handler and the prototype for the Host's callback are shown here:

10 `void TaskMsgHandler(T_ReplyRef replyref, T_MsgID MsgID, T_Count count, T_DSP_Word *buf);`
`void HostCallBack(T_ReplyRef replyref, T_MsgID MsgID, T_Count count, T_DSP_Word *buf);`

15 [0055] The *replyref* parameter refers to an implementation dependent reference value, which is used to route the reply back to the sender. For every *Send_Message* call, the recipient must call *Reply_Message* using the *replyref* parameter. The actual messages may appear as follows:

20

| | | | | | | |
|----------------|------------|--------|----------|-------|-------|-----------|
| Sent message: | MsgPktFlag | taskid | replyref | msgid | count | buf[....] |
| Reply message: | MsgPktFlag | -1 | replyref | msgid | count | buf[....] |

The multiword data is sent least-significant word first.

25 [0056] A *TaskID* of 0 in the *Send_Message* function indicates a system level message. The system level messages are used to implement the DSP-API functions

[0057] Following are the Message functions:

Send_Message

30 `BOOL Send_Message(T_TaskID TaskID, T_MsgID MsgID, T_Count count, T_DSP_Word *msgbuf, T_DSP_Word *replybuf, T_Size replybufsize, T_Count replycount, U16 *errcode);`

35 [0058] This function will send a user defined message to a task specified by *TaskID*. The *MsgID* defines the message, and the *msgbuf* contains the actual message data. The message size is *count* T_DSP_Words. The reply to the message will be contained in the *replybuf* parameter, which points to a buffer of size *replybufsize*, provided by the caller. It should be of sufficient size to handle the reply for the particular message. The *errcode* parameter will contain the following possible results:

40 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_TASK_NOT_FOUND

Reply_Message

`BOOL Reply_Message(T_ReplyRef replyref, T_Count count, T_DSP_Word *buf, U16 *errcode);`

50 [0059] This function is used to reply to messages. The *replyref* parameter is a reference used to route the reply back to the sender of the original message, and is implementation specific. The reply is contained in the *buf* parameter and its size is *count* T_DSP_Words. The *errcode* parameter will contain the following possible results:

55 DSP_SUCCESS
 DSP_DEVID_NOT_FOUND
 DSP_DEVID_NOT_RESPONDING
 DSP_BAD_REPLY_REF

Channels

[0060] The concept of channels is used to transmit frame-based data from one processor to another, or between tasks on the same processor. When created, a channel allocates a specified number and size of frames to contain the data.

5 Initially, the channel will contain a list of empty frames. Tasks that produce data will request empty frames in which to put the data, then once filled, the frame is returned to the channel. Tasks that consume data will request full frames from the channel, and once emptied, the frame is returned to the channel. This requesting and returning of frame buffers allows data to move about with a minimum of copying.

[0061] Each task has a specified Input and Output channel. Once a channel is created, it should be designated as 10 the input to one task, and the output to another task. A channel's ID includes a device ID, so channels can pass data between processors. Channel data flow across the Host-DSP interface may appear as follows:

15

| | | | |
|-------------|------------|-------|-----------|
| ChanPktFlag | Channel ID | Count | Data[...] |
|-------------|------------|-------|-----------|

The following are the channel functions:

20 **Create_Channel**

*BOOL Create_Channel(T_DeviceID DevID, T_Size framesize, T_Count numframes, T_ChainID *ChannelID, U16 *errcode);*

25 [0062] This function creates a data frame-based communication channel. This creates a channel control structure, which maintains control of a set of frame buffers, whose count and size are specified in the *numframes* and *framesize* parameters, respectively. When created, the channel allocates the data frames, and adds them to its list of empty frames. *ChannelID* will return the ID of the new channel. If the *DevID* is not that of the calling processor, a channel control structure is created on both the calling processor and the *DevID* processor, to control data flowing across the communications interface. The *errcode* parameter will contain the following possible results:

35

CHAN_SUCCESS
CHAN_DEVID_NOT_FOUND
CHAN_DEVID_NOT_RESPONDING
CHAN_ALLOCATION_ERROR

Delete_Channel

*BOOL Delete_Channel(T_ChainID ChannelID, U16 *errcode);*

40

[0063] This function deletes an existing channel specified by *ChannelID*. The *errcode* parameter will contain the following possible results:

45

CHAN_SUCCESS
CHAN_DEVID_NOT_FOUND
CHAN_DEVID_NOT_RESPONDING
CHAN_CHANNEL_NOT_FOUND

Request_Empty_Frame

50

*BOOL Request_Empty_Frame(T_LocalChainID Chn, T_DSP_Word **bufptr, BOOL WaitFlag, U16 *errcode);*

[0064] This function requests an empty frame from the specified local channel ID. If *Chn* is NULL, then the task's output channel is used. Upon return, the *bufptr* parameter will contain the pointer to the frame buffer. If the *WaitFlag* is 55 TRUE, and there is no frame buffer available, the caller will be suspended until a buffer becomes available. If the *WaitFlag* is FALSE, the function will return regardless. The *errcode* parameter will contain the following possible results:

CHAN_SUCCESS

CHAN_CHANNEL_NOT_FOUND
CHAN_BUFFER_UNAVAILABLE

Return_Full_Frame

5 BOOL Return_Full_Frame(*T_LocalChanID Chn*, *T_DSP_Word *bufptr*, *U16 *errcode*);

[0065] Once a task has filled a frame buffer, it returns to the channel using this function. The buffer pointed to by *bufptr* is returned to the channel ID specified. If *Chn* is NULL, then the task's output channel is used. The *errcode* parameter will contain the following possible results:

CHAN_SUCCESS
CHAN_CHANNEL_NOT_FOUND
CHAN_BUFFER_CTRL_ERROR

15 Request_Full_Frame

BOOL Request_Full_Frame(*T_LocalChanID Chn*, *T_DSP_Word **bufptr*, *BOOL WaitFlag*, *U16 *errcode*);

20 [0066] This function requests a full frame of data from the specified local channel ID. If *Chn* is NULL, then the task's input channel is used. Upon return, the *bufptr* parameter will contain the pointer to the frame buffer. If the *WaitFlag* is TRUE, and there are no full frame buffers available, the caller will be suspended until a buffer becomes available. If the *WaitFlag* is FALSE, the function will return regardless. The *errcode* parameter will contain the following possible results:

25 CHAN_SUCCESS
CHAN_CHANNEL_NOT_FOUND
CHAN_BUFFER_UNAVAILABLE

Return_Empty_Frame

30 BOOL Return_Empty_Frame(*T_LocalChanID Chn*, *T_DSP_Word *bufptr*, *U16 *errcode*);

[0067] Once a task has used the data from a frame buffer, it should return the buffer to the channel using this function. The buffer pointed to by *bufptr* is returned to the channel ID specified. If *Chn* is NULL, then the task's input channel is used. The *errcode* parameter will contain the following possible results:

CHAN_SUCCESS
CHAN_CHANNEL_NOT_FOUND
CHAN_BUFFER_CTRL_ERROR

40 Set_Task_Input_Channel

BOOL Set_Task_Input_Channel(*T_Task *TaskID*, *T_ChainID ChanID*, *U16 *errcode*);

45 [0068] This function sets a task's input channel to the specified channel ID. The *errcode* parameter will contain the following possible results:

CHAN_SUCCESS
CHAN_DEVID_NOT_FOUND
CHAN_DEVID_NOT_RESPONDING
CHAN_TASK_NOT_FOUND
CHAN_CHANNEL_NOT_FOUND

55 Set_Task_Output_Channel

BOOL Set_Task_Output_Channel(*T_Task *TaskID*, *T_ChainID ChanID*, *U16 *errcode*);

[0069] This function sets a task's output channel to the specified channel ID. The *errcode* parameter will contain the

following possible results:

5 CHAN_SUCCESS
 CHAN_DEVID_NOT_FOUND
 CHAN_DEVID_NOT_RESPONDING
 CHAN_TASK_NOT_FOUND
 CHAN_CHANNEL_NOT_FOUND

Streams

10 [0070] Streams are used for data, which can not be broken into frames, but which continuously flow into and out of a task. A stream will consist of a circular buffer (FIFO) with associated head and tail pointers to track the data as it flows in and out. Each task can have a designated input and output stream. Stream data flow across the Host-DSP interface may appear as follows:

15

| | | | |
|-------------|-----------|-------|-----------|
| StrmPktFlag | Stream ID | Count | Data[...] |
|-------------|-----------|-------|-----------|

20

Following are the stream functions:

Create_Stream

25 *BOOL Create_Stream(T_DeviceID DevID, T_Size FIFOsize, T_StrmID *StreamID, U16 *errcode);*

[0071] This function creates a FIFO-based communication stream. This creates a stream control structure, which maintains control of a FIFO of size *FIFOsize*. When created, the stream allocates an empty FIFO, and initializes head and tail pointers to handle data flow into and out of the stream. *StreamID* will return the ID of the new stream. If the *DevID* is not that of the calling processor, a stream control structure is created on both the calling processor and the *DevID* processor, to control data flowing across the communications interface. The *errcode* parameter will contain the following possible results:

35

 STRM_SUCCESS
 STRM_DEVID_NOT_FOUND
 STRM_DEVID_NOT_RESPONDING
 STRM_ALLOCATION_ERROR

Delete_Channel

40

*BOOL Delete_Stream(T_StrmID StreamID, U16 *errcode);*

[0072] This function deletes an existing stream specified by *StreamID*. The *errcode* parameter will contain the following possible results:

45

 STRM_SUCCESS
 STRM_DEVID_NOT_FOUND
 STRM_DEVID_NOT_RESPONDING
 STRM_STREAM_NOT_FOUND

50

Get_Stream_Count

*BOOL Get_Stream_Count(T_LocalStrmID StrmID, T_Count *count, U16 *errcode);*

55

[0073] This function requests the count of T_DSP_Words currently in the stream FIFO specified by *StrmID*. The *count* parameter will contain the number upon return. The *errcode* parameter will contain the following possible results:

 STRM_SUCCESS

STRM_STREAM_NOT_FOUND

Write_Stream

5 `BOOL Write_Stream(T_LocalStrmID Strm, T_DSP_Word *bufptr T_Count count, T_Count *countwritten, U16 *errcode);`

[0074] This function will write `count` number of `T_DSP_Words` to the stream specified by the `Strm`. If `Strm` is `NULL`, the task's output stream is used. The data is pointed to by the `bufptr` parameter. Upon return, `countwritten` will contain `count` the number of `T_DSP_Words` actually written. The `errcode` parameter will contain the following possible results:

15 STRM_SUCCESS
 STRM_DEVID_NOT_FOUND
 STRM_DEVID_NOT_RESPONDING
 STRM_STREAM_NOT_FOUND
 STRM_STREAM_OVERFLOW

Read_Stream

20 `BOOL Read_Stream(T_LocalStrmID Strm, T_DSP_Word *bufptr, T_Count maxcount, BOOL WaitFlag, T_Count *countread U16 *errcode);`

[0075] This function reads data from the stream specified by `Strm`. If `Strm` is `NULL`, the task's input stream is used. The data will be stored in the buffer pointed to by `bufptr`. Up to `maxcount` `T_DSP_Words` will be read from the stream. The `countread` parameter will contain the actual count of the data read. The `errcode` parameter will contain the following possible results:

30 STRM_SUCCESS
 STRM_DEVID_NOT_FOUND
 STRM_DEVID_NOT_RESPONDING
 STRM_STREAM_NOT_FOUND

Set_Task_Input_Stream

35 `BOOL Set_Task_Input_Stream(T_Task *TaskID, T_StrmID StrmID, U16 *errcode);`

[0076] This function sets a task's input stream to the specified stream ID. The `errcode` parameter will contain the following possible results:

40 STRM_SUCCESS
 STRM_DEVID_NOT_FOUND
 STRM_DEVID_NOT_RESPONDING
 STRM_TASK_NOT_FOUND
 STRM_STREAM_NOT_FOUND

Set_Task_Output_Stream

`BOOL Set_Task_Output_Stream(T_Task *TaskID, T_StrmID StrmID, U16 *errcode);`

50 [0077] This function sets a task's output stream to the specified stream ID. The `errcode` parameter will contain the following possible results:

55 STRM_SUCCESS
 STRM_DEVID_NOT_FOUND
 STRM_DEVID_NOT_RESPONDING
 STRM_TASK_NOT_FOUND
 STRM_STREAM_NOT_FOUND

DATA TYPES

[0078] Data types used herein are defined in Table 3:

5

Table 3

| Symbol | Description |
|-------------------|---|
| S8 | Signed 8-bit integer. |
| 10 U8 | Unsigned 8-bit integer. |
| S16 | Signed 16-bit integer. |
| 15 U16 | Unsigned 16-bit integer. |
| S32 | Signed 32-bit integer. |
| 20 U32 | Unsigned 32-bit integer. |
| T_HostWord | A word on the Host processor. |
| T_DSP_Word | A word on the DSP processor. |
| 25 BOOL | Boolean value (TRUE or FALSE). |
| T_HostPtr | Pointer on the Host processor. |
| T_DSP_Ptr | Pointer on the DSP processor. |
| 25 T_DeviceID | Processor device ID. |
| T_TaskID | A structure containing fields for a device ID and a processor local task ID. |
| T_ChainID | A structure containing fields for a device ID and a processor local channel ID. |
| 30 T_MsgID | Message ID. |
| T_DSP_ID | An object ID on the DSP. |
| T_Count | Data type for a count. |
| T_Size | Data type for a size. |
| 35 T_HostCallBack | Value used when tasks send message back to the Host. |
| T_ReplyRef | Message reply reference. |
| T_LocalTaskID | Local task ID. |
| T_LocalChainID | Local channel ID. |
| 40 T_DSP_Name | Name for DSP objects (RTOS dependent). |
| T_CodeHdr | Code header structure for a DSP Library entry. |
| T_TaskCreate | Task creation structure. |

45

SYSTEM MESSAGES

[0079] These tables define the messages passing between devices (i.e. Host to DSP 16). The device IDs present as parameters in the corresponding function calls are not incorporated in the messages since they are used to actually route the message to the device. Similarly, task IDs that include a device ID as their upper half for the function call will not include the device ID in the message, but only the DSP's local task ID portion.

55

Table 4

| DSP-API Messages | | | | |
|------------------|-----------------|---|--|----------------------|
| | Message | Send Parameters | Reply Parameters | Direction Host ↔ DSP |
| 5 | GET_MIPS | None | U32 mips | → |
| 10 | GET_MEM_AVAIL | | T_Size progmem T_Size datamem | → |
| 15 | ALLOC_MEM | U16 mempage T_Size size | T_DSP_Word *memptr U16 errcode | → |
| 20 | FREE_MEM | U16 mempage T_DSP_Word *memptr | U16 errcode | → |
| 25 | PUT_BLOB | T_DSP_Ptr destaddr U16 mempage T_Size size T_DSP_Word BLOB[size] | U16 errcode | → |
| 30 | CREATE_TASK | T_TaskCreate tcs | T_TaskID TaskID U16 errcode | → |
| 35 | START_TASK | T_TaskID TaskID | U16 errcode | → |
| 40 | SUSPEND_TASK | T_TaskID TaskID | U16 errcode | → |
| 45 | RESUME_TASK | T_TaskID TaskID | U16 errcode | → |
| | DELETE_TASK | T_TaskID TaskID | U16 errcode | → |
| | CHANGE_PRIORITY | T_TaskID TaskID U16 newpriority | U16 oldpriority U16 errcode | → |
| | GET_TASK_STATUS | T_TaskID TaskID | U16 status U16 priority T_ChainID Input T_ChainID Output U16 errcode | → |
| | GET_ID | T_DSP_Name Name | T_DSP_ID ID U16 errcode | → |

Table 5

| DSP Interface Layer / Channel Interface Layer Messages | | | | |
|--|----------------|---------------------------------------|------------------------------------|----------------------|
| | Message | Send Parameters | Reply Parameters | Direction Host ↔ DSP |
| 50 | CREATE_CHANNEL | T_Size framesize T_Count numframes | T_ChainID ChannelID U16 errcode | → |
| 55 | DELETE_CHANNEL | T_ChainID ChannelID | U16 errcode | → |

Table 5 (continued)

| DSP Interface Layer / Channel Interface Layer Messages | | | |
|--|-------------------|----------------------------------|----------------------|
| Message | Send Parameters | Reply Parameters | Direction Host ↔ DSP |
| CREATE_STREAM | T_Size FIFOsize | T_StrmID StreamID U16 errcode | → |
| DELETE_STREAM | T_StrmID StreamID | U16 errcode | → |

5

10

15

Table 6

| Debug Messages | | | |
|----------------|---|--------------------------------------|----------------------|
| Message | Send Parameters | Reply Parameters | Direction Host ↔ DSP |
| READ_MEM | U16 mempage T_DSP_Ptr addr T_Count count | T_DSP_Word mem[count] U16 errcode | → |
| WRITE_MEM | U16 mempage T_DSP_Ptr addr T_Count count T_DSP_Word mem[count] | U16 errcode | → |
| READ_REG | U16 RegID | DSP_WORD regvalue U16 errcode | → |
| WRITE_REG | U16 RegID T_DSP_Word regvalue | U16 errcode | → |
| SET_BREAK | T_DSP_Ptr addr | U16 errcode | → |
| CLR_BREAK | T_DSP_Ptr addr | U16 errcode | → |
| BREAK_HIT | T_DSP_Ptr addr | U16 ACK | ↔ |

40

DOWNLOADING NATIVE CODE

[0080] Figures 4 - 6 illustrate an embodiment for downloading native code to a target processor (i.e., the host 12 or DSP 16) in a secure and efficient manner. This embodiment for downloading code could be used, for example, in downloading code from the Internet, or other global network, from a Local or Wide Area Network, or from a peripheral device, such as a PC Card or Smartcard.

[0081] In Figure 4, an embodiment of a JAVA Bean 90 is shown, where the Bean 90 acts as a wrapper for native code 92. The Bean further includes several attributes 94, listed as a Code Type attribute 94a, a Code Size attribute 94b and a MIPS Required attribute 94c. The Bean 90 has several actions 96, including a Load Code action 96a, a Load Parameters action 96b and an Execute Parameter 96c.

[0082] In operation, the Load Code action 96a is used to load external native code (native to the target processor) into the Bean. Since JAVA Beans have persistence, the Bean 90 can store its internal state, including the native code 92 and the attributes 94. The Load Parameters action 96b retrieves parameters from the native code 92 (using, for example, the COFF file format described above) and stores the parameters as attributes 94a-c. The Execute action 96c executes tasks installed in the DSP 16.

[0083] Figure 5 illustrates use of the Bean 90 to download code to the target processor. In this example, it is assumed that the target processor is the DSP 16 (or one of multiple DSPs 16), although it could be used to download native code to the host processor 12 as well. Further, it is assumed that the desired Bean 90 is resident in a network server, such

as a LAN server or an Internet server, although the Bean could be resident in any device in communication with the platform 10, such as a Smartcard. For a wireless data platform 10, the connection to the network server 100 will often be wireless.

[0084] In Figure 5, the platform 10 is coupled to a network server 100. The host processor 12, as shown in greater detail in Figure 2, may execute one or more JAVA applets 40 through a JAVA virtual machine 44. In order to download new code, the host 12 loads an applet containing the Bean 90 from the network server 100 or the Bean, without the containing applet, can be downloaded from the server 100. Once the wrapper Bean 90 has been retrieved, it can be queried for the size of the native code, code type (for which processor is the code intended) and MIPs required. If the intended processor has sufficient resources to run the code 92, the code 92 can be installed to execute on the intended processor, either the host processor 12 or DSP 16 in the architecture shown in Figure 5. Typically, the native code 92 will be unlinked, compiled code. Thus, the cross linker 82 of the DSP-API 50 will link the code to a available memory location. The Bean would pass the binary native code 92 to the dynamic cross linker 82, which would install and execute the code.

[0085] A typical manner in which a download of native code might occur is when the user is running an applet in which a DSP function is desired. First, the applet would check to see if the desired code was installed as a task 60 in the DSP or was available in the DSP Library 58. If so, the task could be executed without a download.

[0086] If the task is not stored in the DSP 16 or the DSP library 58, an object (referred to as the "DSPLoader" object herein) could be created to load the Bean 90. If the DSPLoader class is local on the host 12, JAVA will check to see if the Bean is available locally as well. In a first instance, there may be a Bean with the code stored locally. If so, the code from the Bean is installed to the DSP (or to whichever processor specified by the Code Type). If a Bean without the code is stored locally, the Bean can retrieve the code from the appropriate server.

[0087] On the other hand, if the DSPLoader object is not local, then JAVA will load the Bean 90 from the server that wrote the applet. The code from the Bean will then be installed as described above.

[0088] While the downloading of native code is described in connection with the use of a JAVA Bean, it could also be accomplished by wrapping the code within another language, such as an ActiveX applet.

[0089] Using a JAVA Bean (or other applet) as a wrapper to the native code has significant advantages. First, it allows a simple, standard method for loading code onto one of a plurality of processors. The Bean is created, code is loaded into the Bean and the code is linked to the appropriate processor. Without wrapping the code within the Bean, the process may take several hundred steps. Second, it allows multiple pieces of native code to be combined by a single applet, providing for complex applications to be generated from multiple discrete routines using a single applet to combine the routines as desired. Third, it takes advantage of the language's security features, thereby protecting not only the JAVA code in the Bean 90, but the native code 92 as well. Other languages, such as ActiveX, have security features as well.

SECURITY

[0090] Two of the most important security features are digital signing and encryption. A JAVA Bean or ActiveX applet may be signed by the source of the code; when the Bean or applet is downloaded, the signature is verified by the receiving application, which has a list of trusted sources. If the Bean or applet is signed by a trusted source, it can be decrypted using standard techniques. Accordingly, the native code is encrypted during transmission along with the code of the Bean or applet, preventing unauthorized modification of the code. Because the native code is secure and comes from a trusted source, the attributes can also be trusted as accurate.

[0091] Figure 6 illustrates a flow chart describing the process of downloading native code for a processor using a JAVA Bean, it being understood that the native code could be wrapped in an applet of a different language using similar techniques. In step 110, the encrypted, digitally signed Bean 90 is downloaded to a device running a JAVA virtual machine. In step 112, the signature is verified. If it is not from a source listed as a trusted source, exception processing is enabled in step 114. In the case of the Bean coming from a trusted source, the exception processing function may give the user an opportunity to accept the Bean, if the user is comfortable with the source. If the signature is invalid, the exception processing may delete the Bean 90 and send an appropriate error message to the user.

[0092] If the signature is valid and comes from a trusted source, the Bean is decrypted in step 116. This step decrypts both the JAVA code and the native code in the Bean. In step 118, the attributes are retrieved from the Bean 90 and in step 120 the applet determines whether the appropriate processor has sufficient resources to run the code. If not, the exception processing step 114 may decline to install the native code, or steps may be taken to free resources. If there are sufficient resources, the code is linked using the cross-linker and installed on the desired processor in step 122. In step 124, the native code is executed.

[0093] Sample JAVA script for a Bean 90 is provided hereinbelow:

```
package ti.dsp.loader;  
5  
import java.awt.*;  
import java.io.*;  
import java.net.*;  
  
public class NativeBean extends Canvas implements Serializable  
10  
{  
    public NativeBean() {  
  
        setBackground(Color.white);  
15  
        funcData = new ByteArrayOutputStream();  
  
        try {  
            funcCodeBase = new URL("http://localhost");  
20  
        }  
        catch (MalformedURLException e) {  
  
25  
    }  
  
30  
  
35  
  
40  
  
45  
  
50  
  
55
```

```

        }

5    public Dimension getMinimumSize() {
        return new Dimension(50, 50);
    }

10   public void loadCode() {
        URL baseURL = null;

15   try {
        baseURL = new URL(funcCodeBase.toString() + "/" + myFunction);
    }
    catch (MalformedURLException e) {
    }

20   DataInputStream source = null;
        int read;
        byte[] buffer;

25   buffer = new byte[1024];
        try {
            source = new DataInputStream(baseURL.openStream());
        }
        catch (IOException e) {
            System.out.println("IOException creating streams: " + e);
        }

35   codeSize = 0;
        funcData.reset();

40   try {
        while (true) {
            read = source.read(buffer);

45   if (read == -1)
            break;

            funcData.write(buffer, 0, read);
        }
    }
    catch (IOException e) {
        System.out.println("IOException: " + e);
    }
}

```

55

```

codeSize = funcData.size();
System.out.println("Code size = " + codeSize);

5      try {
           source.close();
       }
       catch (IOException e) {
           System.out.println("IOException closing: " + e);
       }
   }

15     public synchronized String getFunctionName() {
           return myFunction;
       }

20     public void setFunctionName(String function) {
           myFunction = function;
       }

25     public synchronized String getCodeBase() {
           return funcCodeBase.toString();
       }

30     public void setCodeBase(String newBase) {
           try {
               funcCodeBase = new URL(newBase);
           }
           catch (MalformedURLException e) {
           }
       }

35     public void installCode() {
           FileOutputStream destination = null;
           File libFile = new File(myFunction);

40           try {
               destination = new FileOutputStream(libFile);
           }
           catch (IOException e) {
               System.out.println("IOException creating streams: " + e);
           }

45           if (destination != null) {

```

```

try {
    funcData.writeTo(destination);
}
5
catch (IOException e) {
    System.out.println("IO Exception installing native code: " + e);
}
}
10
linkCode(funcData)

15
public void loadParameters() {
}

public void execute() {
}

20
public synchronized int getCodeSize() {

    return codeSize;
}
25
public synchronized int getCodeType() {

    return codeType;
}
30
public void setCodeType(int newType) {

    codeType = newType;
}
35
40
private int codeSize = 0;
private int codeType = 1;
private String myFunction = "";
private URL funcCodeBase = null;
private ByteArrayOutputStream funcData = null;
}
45

```

[0094] In the script set forth above, the NativeBean() routine creates the Bean 90 which will hold the native code. The loadCode() routine gets the native code from the server. The getFunctionName() and getCodeBase() routines retrieve attributes. The installCode() routine calls the cross linker to link the native code to the DSP and to load the linked code.

50 The loadParameters() routine instructs the Bean to examine the native code and determine its attributes. The getCodeSize() and getCodeType() routines transfer the attributes to the requesting applet.

[0095] Although the Detailed Description of the invention has been directed to certain exemplary embodiments, various modifications of these embodiments, as well as alternative embodiments, will be suggested to those skilled in the art. The invention encompasses any modifications or alternative embodiments that fall within the scope of the Claims.

55 [0096] The scope of the present disclosure includes any novel feature or combination of features disclosed therein either explicitly or implicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed by the present invention. The applicant hereby gives notice that new claims may be formulated to such features during the prosecution of this application or of any such further application

derived therefrom. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the claims.

5 [0097] Further and particular embodiments of the invention will now be enumerated by way of the following numbered clauses.

1. A method of controlling an electronic device comprising

10 external to said electronic device, storing a file of native code within an software program comprising source code;
encrypting both the source code and the native code in said software program;
downloading the software program to said electronic device;
decrypting said software program;
15 retrieving said native code from the software program;
installing said native code on a target processor; and
executing said native code on said target processor.

2. The method of clause 1 wherein said downloading step comprises the step of downloading the software program from a global network.

20 3. The method of clause 2 wherein said downloading step comprises the step of downloading the software program from an Internet server.

4. An electronic device comprising:

25 circuitry for coupling to an external device storing a file of native code within an software program comprising source code, said external device encrypting both the source code and the native code in said software program;
a host processor for:

30 downloading the software program to said electronic device;
decrypting said software program;
retrieving said native code from the software program;
installing said native code on a target processor; and
initiating the execution of said native code.

35 5. The electronic device of clause 4 wherein said software program comprises a JAVA Bean.

6. The electronic device of clause 4 or 5 wherein said external device comprises a global network server.

7. The electronic device of any of clauses 4 to 6 wherein said external device comprises an Internet server.

8. The electronic device of any of clauses 4 to 7 wherein said target processor is a digital signal processor.

9. An electronic device comprising:

40 circuitry for coupling to an external device storing a file of native code within an software program comprising source code, said external device applying a digital signature to said software program;
a host processor for:

45 downloading the software program to said electronic device;
verifying said digital signature;
retrieving said native code from the software program responsive to said verifying step;

50 installing said native code on a target processor; and
initiating the execution of said native code.

10. The electronic device of clause 9 wherein said target processor is a digital signal processor.

Claims

55

1. A method of controlling an electronic device comprising:

external to said electronic device, storing a file of native code within an software program comprising source

code;

encrypting both the source code and the native code in said software program, downloading the software program to said electronic device;

decrypting said software program;

5 retrieving said native code from the software program; installing said native code on a target processor; and executing said native code on said target processor.

2. The method of claim 1 wherein said software program comprises a JAVA Bean.

10 3. The method of claim 1 or claim 2 and further comprising the step of appending a digital signature to said software program.

15 4. The method of claim 3 and farther comprising the steps of reading said digital signature from said software program and comparing said digital signature to a list of trusted sources.

5 5. The method of any preceding claim wherein said software program further comprises attributes associated with said native code.

20 6. The method of claim 5 and farther comprising the step of encrypting said attributes.

7. A method of controlling an electronic device comprising:

25 external to said electronic device, storing a file of native code within an software program comprising source code;

applying a digital signature to said software program;

downloading the software program to said electronic device;

retrieving said native code from the software program;

30 verifying said digital signature; installing said native code on a target processor responsive to said verifying step; and executing said native code on said target processor.

8. The method of claim 7 wherein said verifying step comprising the steps of reading said digital signature from said software program and comparing said digital signature to a list of trusted sources.

35 9. The method of claim 7 or 8 and farther comprising the step of encrypting said software program prior to said downloading step.

40 10. The method of claim 8 and farther comprising the step of decrypting said software program after said downloading step.

11. The method of claim 1 or 9 wherein said downloading step comprises the step of downloading the software program from a global network.

45 12. The method of claim 1 or 9 wherein said downloading step comprises the step of downloading the software program from an Internet server.

13. An electronic device comprising:

50 circuitry for coupling to an external device storing a file of native code within an software program comprising source code, said external device encrypting both the source code and the native code in said software program; a host processor for:

55 downloading the software program to said electronic device; decrypting said software program; retrieving said native code from the software program; installing said native code on a target processor; and

initiating the execution of said native code.

14. The electronic device of claim 13 wherein said host processor farther verifies a digital signature associated with said software program.

5

15. An electronic device comprising:

circuity for coupling to an external device storing a file of native code within an software program comprising source code, said external device applying a digital signature to said software program;

10

a host processor for:

downloading the software program to said electronic device;

verifying said digital signature;

retrieving said native code from the software program responsive to said verifying step;

15

installing said native code on a target processor; and

initiating the execution of said native code.

16. The electronic device of any of claims 13 to 15 wherein said software program comprises a JAVA Bean.

20

17. The electronic device of any of claims 13 to 16 wherein said external device comprises a global network server.

18. The electronic device of any of claims 13 to 16 wherein said external device comprises an Internet server.

25

19. The electronic device of any of claims 15 to 18 wherein said software program is encrypted and said host processor further decrypts said software program.

30

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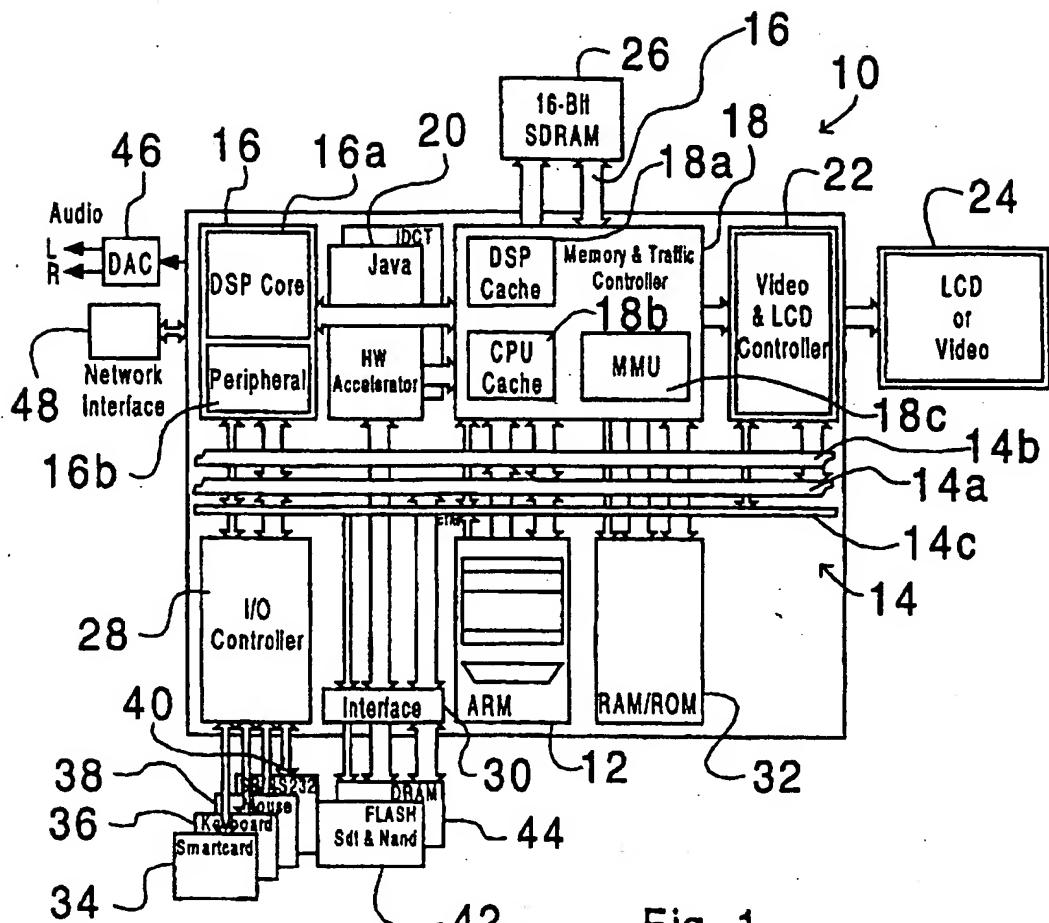
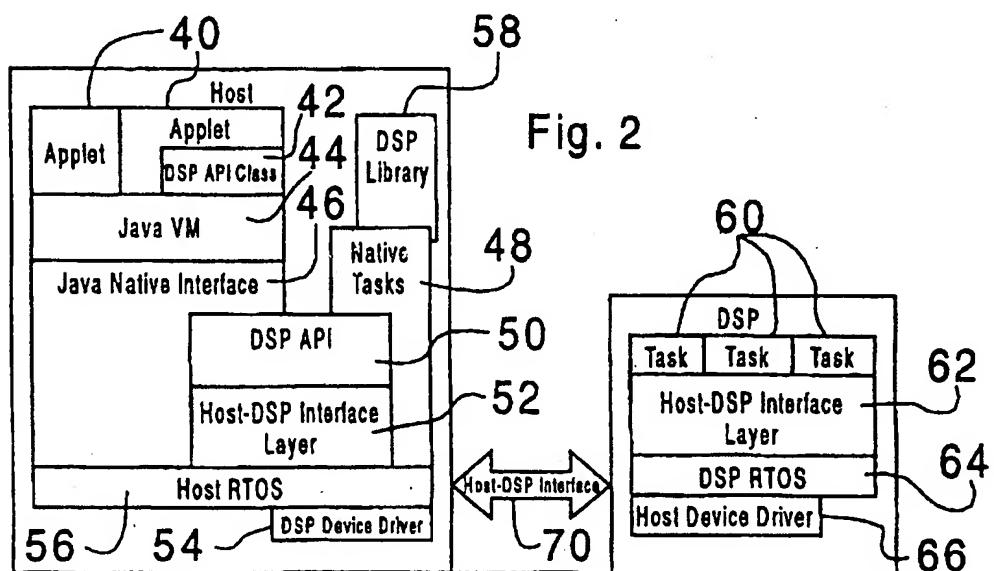


Fig. 1



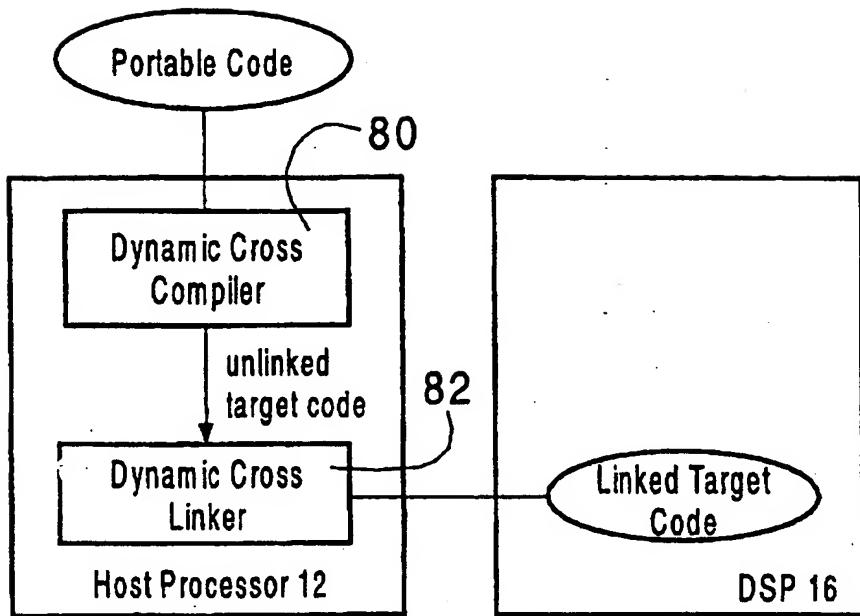


Fig. 3

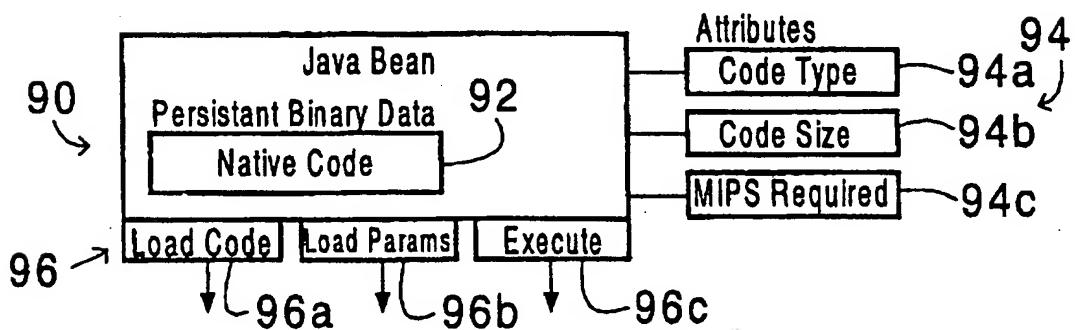


Fig. 4

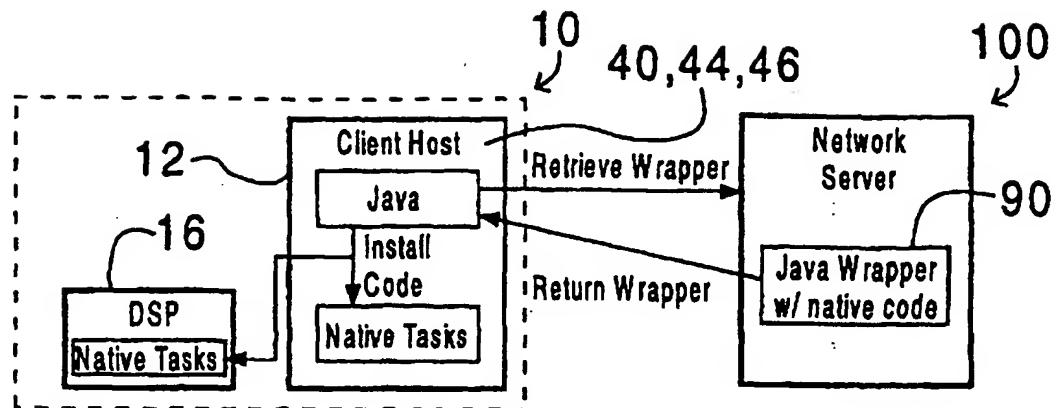


Fig. 5

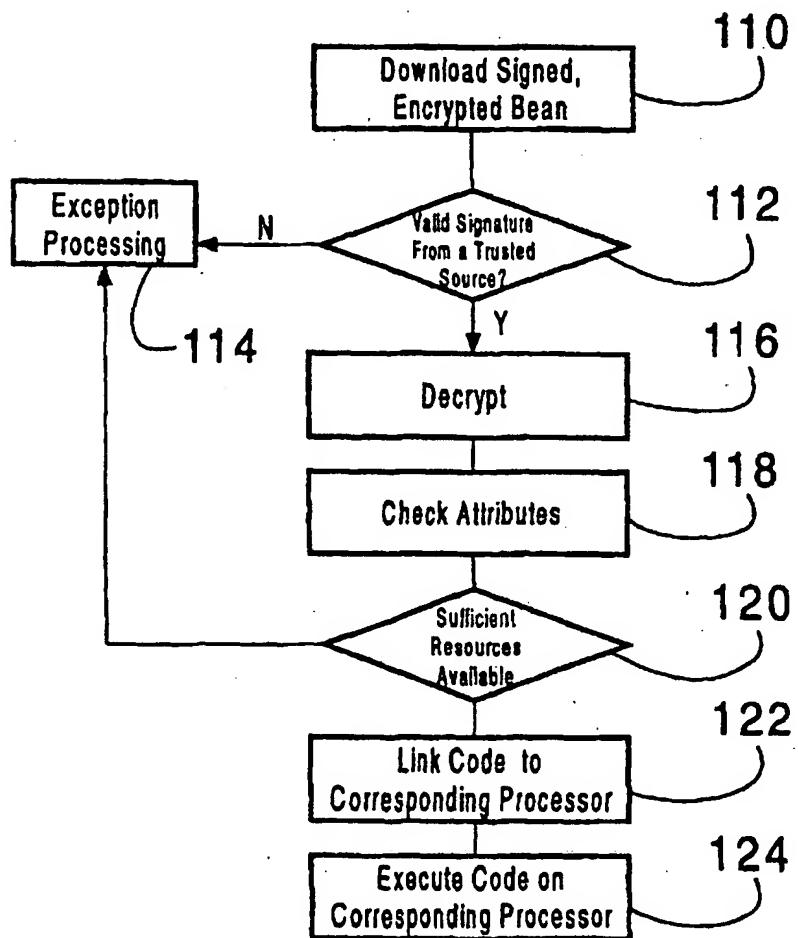


Fig. 6